Letters to the Editor

PROMPT publication of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is the third of the month. Because of the late closing date for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not in general exceed 600 words in length.

Statistical Mechanics of Processes Observed in Cosmic-Ray Phenomena

G. WATAGHIN
University of Sao Paulo, Sao Paulo, Brazil
June 12, 1943

SOME of the processes observed in cosmic rays are obviously irreversible because of the simultaneous or successive creation of many particles, the instability of mesotrons, and the production of neutrinos.[1] We have direct evidence of the successive transformation of the high energy of a primary particle into the energy of many photons and electrons of lower energy (in the cascade showers and in the mesotron showers). Sometimes, in the processes involving emission of neutrinos, an appreciable fraction of this energy escapes any observation.

The statistical laws for such processes are quite different from the usual ones. For some of them only the rate of the irreversible reaction in a given assemblage of particles can be established. At temperatures $T \gtrsim 10^{10}$ degrees ($\kappa T \gtrsim 2mc^2 \sim 10^6$ ev) the thermal equilibrium between photons, electrons, and nuclei will give rise to pair production and radiation processes which we observe in the cascade showers, as well as to processes of "two photons annihilation," and of materialization of two photons.

Let us consider the equilibrium between photons, electrons, positrons, neutrons, protons, and nuclei at $\kappa T > 2mc^2$. Let $N_s\ n_{es}\ n_{ps}\ n_{ns}\ n_{Hs}\ n_{As}{}^Z$ be the numbers of photons, electrons, positrons, neutrons, protons, and nuclei of charge Z and atomic weight A, which belong to the momentum-interval p_s to $p_s + dp_s$. We assume the validity of the laws of conservation of charge ($\Sigma_s\,[n_{ps}+n_{Hs}+Zn_{As}{}^Z-n_{es})$, conservation of energy and conservation of the total number of neutrons and protons. Then, if we indicate by

$$g_s = G(p_s)\frac{8\pi V p_s^2 dp_s}{h^3}$$

the number of quantum states (or eigenvalues of energy) belonging to the sth momentum-interval, we obtain in the usual way[2] a set of expressions of the type:

$$N_s = g_s(e^{\beta h\nu_s}-1)^{-1};\quad n_{es} = g_s(e^{-\alpha+\beta E_s}+1)^{-1};$$
$$n_{Hs} = g_s(e^{\alpha+\gamma+\beta E_{Hs}}+1)^{-1}\quad \cdots \qquad (I)$$

where the factor $G(p_s)$, appearing in g_s, is equal to 1 in the usual quantum mechanics, but is here a function which decreases and vanishes more rapidly than p_s^{-3} for values of p_s greater than a critical value $\sim 137mc$.

Let us assume for β and G_s the accepted values $\beta = 1/\kappa T$ and $G_s = 1$. From Planck's formula we find at once that for $\kappa T > E_0 = 10^8$ ev the number N_1 of photons having $h\nu > E_0$ is greater than the number N_2 of photons having $h\nu < E_0$: $N_1/N_2 \sim 4.8/y_0^2 > 1$ (where $y_0 = E_0/\kappa T < 1$).

This consequence is in contradiction with the irreversibility of the collision processes taking place for high energy photons. From (1) we see how the usual statistical laws could be modified by introduction of $G(p_s)$ in such a way that the total number of quantum states $\Sigma_s\, g_s$ results finite. This idea is in contrast with the basic assumption of the equal probability of equal regions in the phase space, but agrees with the assumption of the existence of a new supplementary indeterminacy in the region of high relative momenta.[3] Full account of the modification of the statistical formulae (I) and of the commutation relations will be published elsewhere. Here we limit ourselves to the following remarks: In the collision of particles in which many mesotrons are produced and β-ray processes are taking part, the laws of conservation of energy and momentum become uncontrollable at least insofar as "neutrinos" or gravitational reactions escape our observation. It signifies also that our possibility to distinguish usual quantum states and measure eigenvalues is limited. A Lorentz transformation with a parameter $(1-\beta^2)^{-\frac{1}{2}} > 100$ transforms some low energy particles into shower-producing cosmic rays. Thus one must introduce new groups of transformations in order to satisfy the principle of covariancy for cosmic-ray phenomena.[3]

[1] See Phys. Rev., March 1 and 15, 1943. The main reason of irreversibility lies in the fact that the inverse processes involve ternary or multiple collisions. The frequency of these collisions is negligible for any reasonable concentration of heavy particles (even at nuclear densities).
[2] Phil. Mag. [7], **17**, 910 (1934); Comptes rendus **203**, 909 (1935).
[3] Nature **142**, 393 (1938); Comptes rendus **207**, 358 (1938); *ibid.* **207**, 421 (1938).

Burst Production in a Gas Volume

M. SINHA
Bose Institute, Calcutta, India
May 15, 1943

ONE of the most interesting cosmic-ray phenomena is the production of bursts during the traversal of high energy particles through thick layers of an absorbing medium. Such bursts are usually investigated with the help of a large pressure ionization chamber surrounded by layers of different absorbing materials. The number of ionizing particles created by the burst is estimated from the total ionization produced in the chamber. When the outer shield is of lead of thickness greater than 10 cm, it is assumed that the burst is due to a high energy mesotron which has imparted a large portion of its energy to a knock-on electron or a photon, and either of these two products then starts a cascade process.

In Wilson chamber photographs taken under large thicknesses of lead, these bursts are seen to occur, and they usually emerge from the lead plates placed above or inside the chamber. A photograph is shown (Fig. 1) in which a burst has started inside the gaseous volume of a Wilson chamber. A lead block 17.5 cm thick was placed